Reduction of Convection in Closed Tube Vapor Growth Experiments

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Abstract

A novel method for suppressing convection during the solidification of material using closed tube physical or chemical vapor transport will be explored. Convection can be suppressed in growth from the melt by application of high magnetic fields but, unfortunately, this technique does not lend itself to vapors, which have no electrical conductivity. Since the Grashof number scales as the cube of the smallest dimension in the flow system, reduction of the size scale can be extremely effective in reducing unwanted convective flows. However, since materials of practical interest must be grown at least on the cm scale, reduction of the overall growth system is not feasible. But if the region just above the growing crystal could be restricted to a few mm, considerable reduction in flow velocity would result. By suspending an effusive barrier in the growth ampoule just above the growth interface, it should be possible to reduce the convective velocity in this vicinity to levels approaching flows in microgravity.

The effusive barrier consists of a disc just slightly smaller than the growth ampoule inside diameter. The disc will be made of a porous material, such as a glass frit, that will allow the vapor to diffuse through, but will act as a barrier to direct flow. It will be positioned at a fixed distance above the growth interface by a series of small magnets imbedded at points around its periphery. The magnets will interact with magnets of opposite polarity placed in the furnace, just outside the growth ampoule. The furnace operating temperatures for most vapor or chemical vapor growth systems are well below the Curie temperature of most magnetic materials, so this should pose no problem. We will use a transparent furnace so that the growth front will be visible. The width of the region between the growth front and the barrier can then be monitored and adjusted if necessary by either adjusting the translation rate of the sample or by moving the magnets on the outside of the furnace.

We will evaluate the effectiveness of the floating effusive barrier in vapor transport growth by growing single crystals of mercurous chloride. This choice was made for several reasons:

- 1. It is a technologically interesting acousto-optical material whose usefulness for device applications is still limited by structural defects that have been shown to be related to convection during the growth process by Singh and co-workers at the former Westinghouse Science and Technology Center (now Northrop-Grumman).
- 2. It is a relatively simple material to grow since it sublimes congruently and grows at low enough temperatures (approximately 400 °C) so that a transparent furnace may be employed to monitor the growth process.
- 3. The material is brightly colored and optically clear at the growth temperature so that the growth interface is easily visible and gross defects can be detected and possibly corrected during the growth process.
- 4. We, at the University of Alabama in Huntsville's Consortium for Materials Development in Space (UAH/CMDS), have had experience in growing this material though a previous cooperative agreement with the Westinghouse Science and Technology Center.

Growth experiments will be carried out with different spacings between the effusive barrier and the growth interface, or the barrier may be moved during an individual growth run. Altering the barrier height changes the amount of convective flows and provides a means for assessing the effects of convection on the quality of the grown material.

Characterization of the grown material will consist primarily of rocking curve data and optical scattering measurements since these are the properties that Dr. Singh and co-workers at Westinghouse found to be most affected by convection. Samples will also be submitted to the National Institute of Standards and Technology (NIST) for topographical analysis on their beam facility at the National Synchrotron Laboratory at Brookhaven. We also have a tentative agreement with the Brimrose Corporation in which they will evaluate the grown materials for potential device applications.

If sufficient improvements result, this floating barrier method could be used as a screening experiment to determine if a proposed flight experiment that involves some form of vapor transport might benefit from a reduction in conduction. Also, the technique might be used to produce a new benchmark material against which future flight results might be judged. Finally, this new growth technique may lead to the production of improved materials on Earth as a microgravity program spin-off.

After having demonstrated improvements in the growth of single crystalline material on Earth, we intend to propose a flight experiment to see if additional improvements are possible by a further reduction in convective flows.